Future Trends of Mediterranean Biodiversity (I)

[Templado J., 2014. Future Trends of Mediterranean Biodiversity. In: Goffredo S., Dubinsky Z. (eds) The Mediterranean Sea: Its history and present challeges. Springer, Dordrecht, p 479-498]

Changing Mediterranean Marine Biodiversity

Change is the rule in biodiversity. Biodiversity, at all its levels, is a changing entity at very different time-scales, from evolutionary to seasonal, or even daily.

Nevertheless, global biodiversity is changing nowadays at an unprecedented rate as a complex response to several human-induced changes in global environment.

Some predictions about the near future (focusing in decadal scale) of marine biodiversity in the Mediterranean Sea are advanced.

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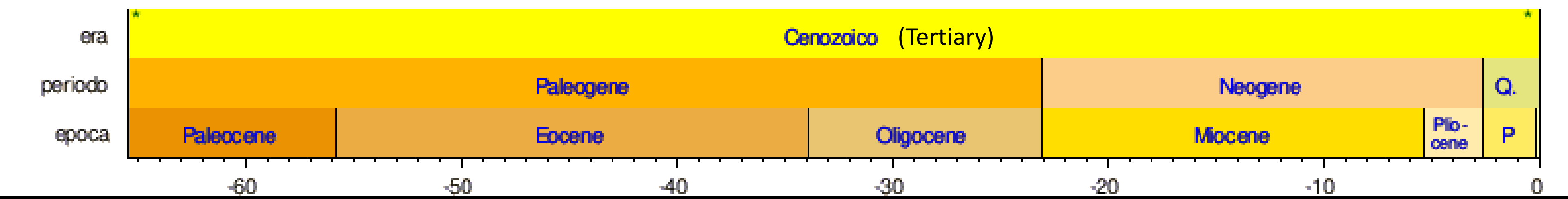
Changing Mediterranean Marine Biodiversity

To place recent rapid changes into context, it is necessary to know both past (long-term) and present (short-term) changes to elucidate the dominant scales of variation and what current biodiversity trends are different from historical trends.



Scala dei tempi geologici

The Mediterranean Fauna and Flora have evolved over millions of years into a unique mixture of temperate and subtropical elements, with a large proportion of endemic species.

The Mediterranean Sea has been subjected to extensive changes in configuration and climate since the Miocene.

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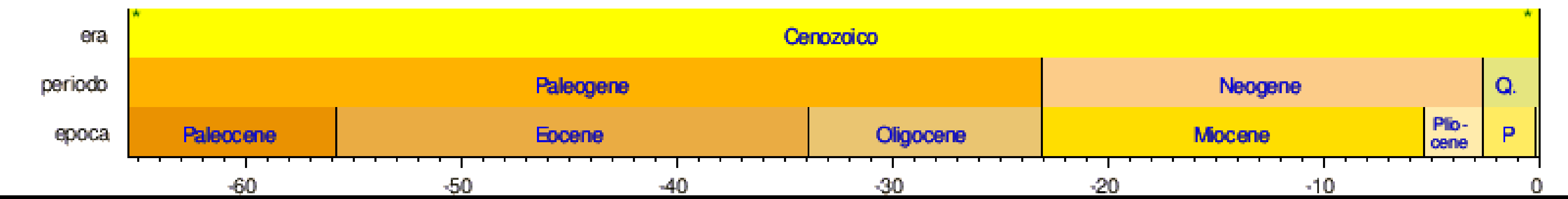
Changing Mediterranean Marine Biodiversity



Scala dei tempi geologici

The combination of events such as the opening/closure of the Strait of Gibraltar, ice cycles and changes in temperature, salinity and current patterns, has apparently made this area a notable generator of diversity.

The alternation of the ice ages with the warm interglacials resulted in different immigration waves of Atlantic fauna of boreal or subtropical origin, respectively.

Because of reduced opportunities for north–south migration in response to changing sea temperatures, the species present within the Mediterranean were subjected to higher evolutionary pressure.

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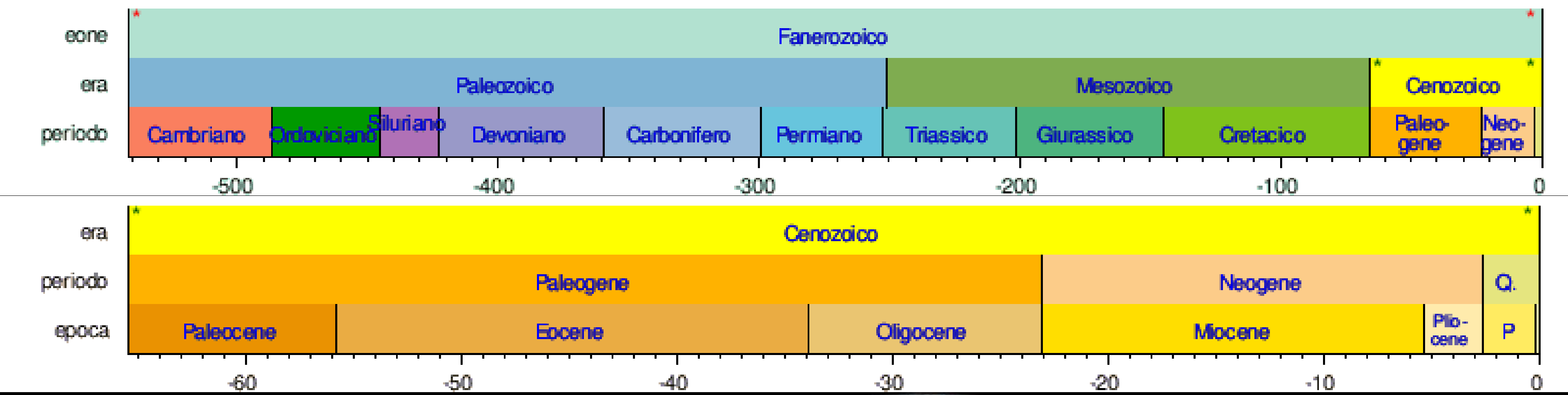
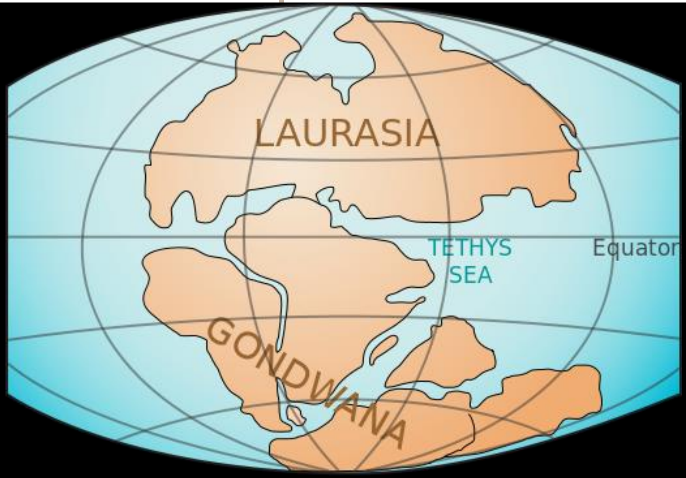


Scala dei tempi geologici

The Mediterranean Sea is a remnant of the once extensive Tethys Ocean, an open equatorial water body that bit into Pangea during the Triassic.



First phase of the Tethys Ocean's forming: the (first) Tethys Sea starts dividing Pangaea into two supercontinents, Laurasia and Gondwana.

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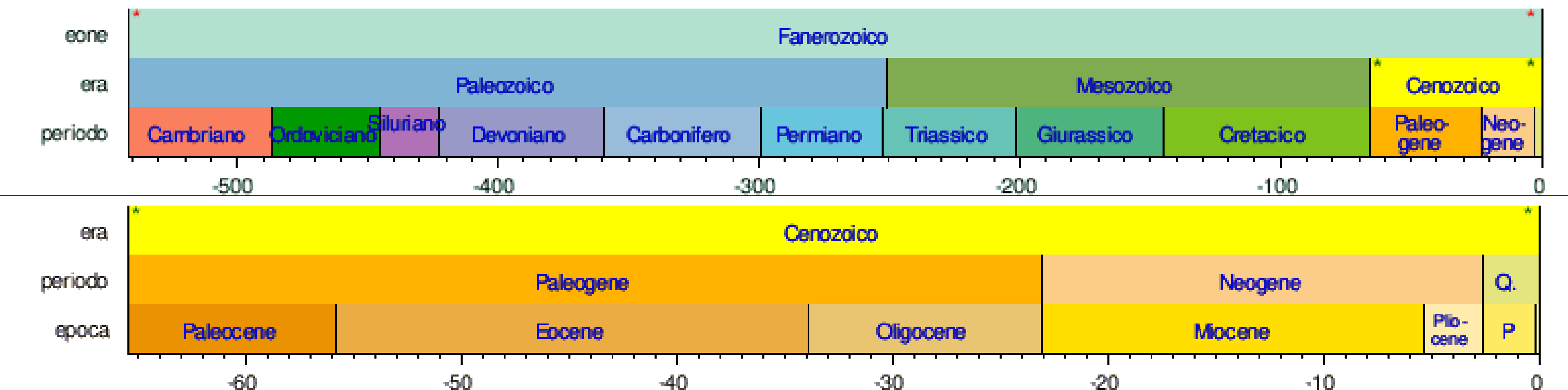
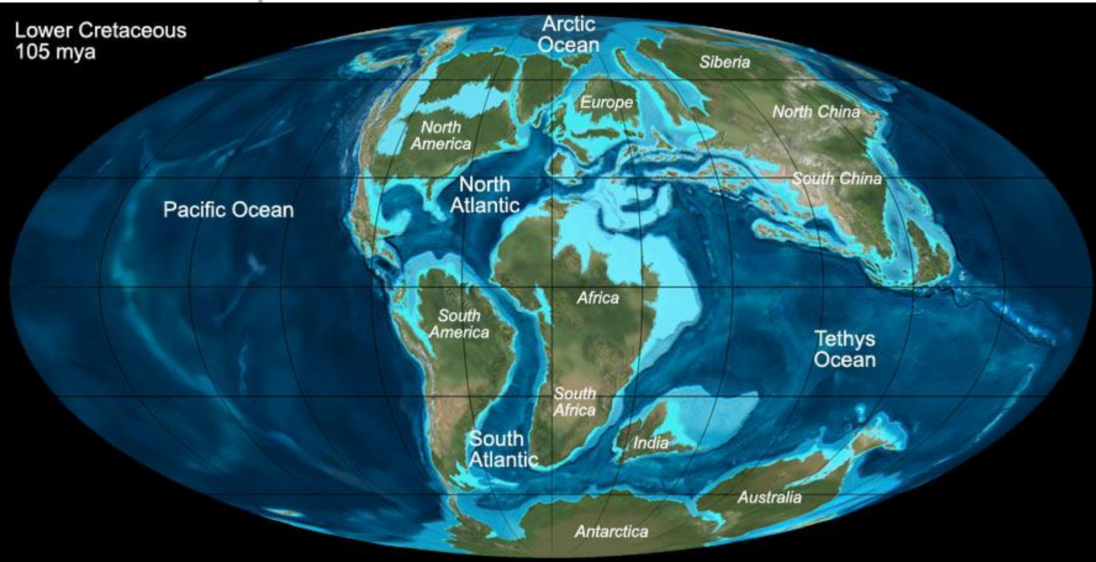
Changing Mediterranean Marine Biodiversity



Scala dei tempi geologici

In the Cretaceous, after the opening of the Atlantic Ocean, Tethys connected the newly born ocean to the older Indo-Pacific Ocean through this equatorial water-body.



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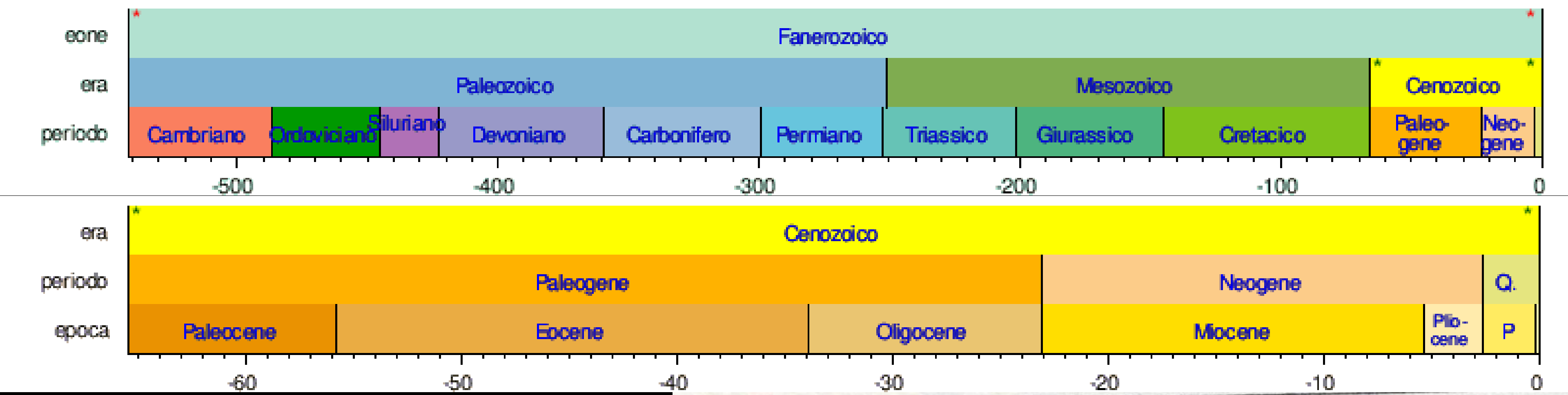
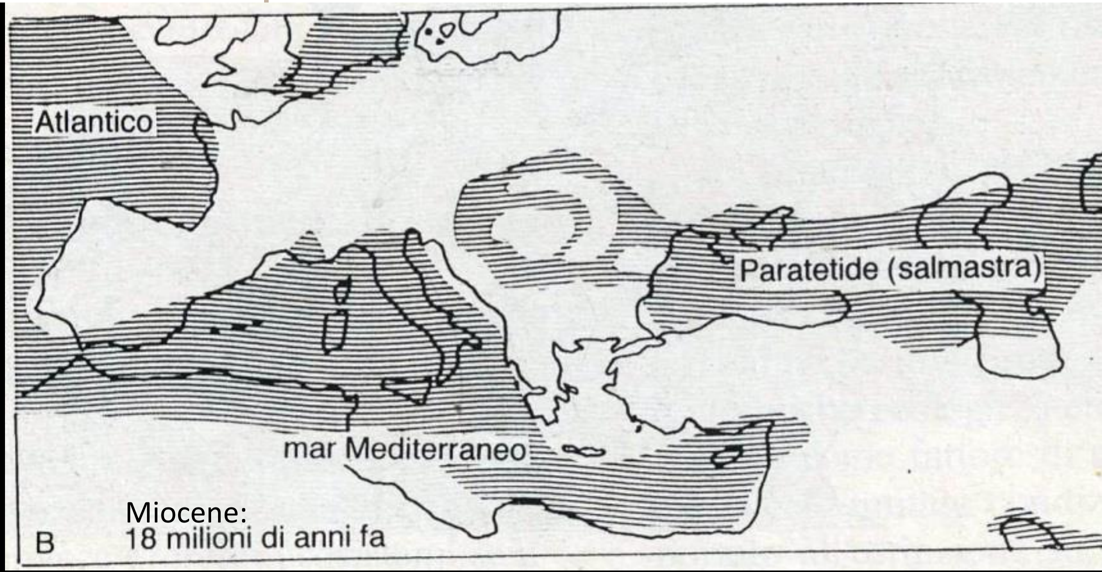


Scala dei tempi geologici

The circumtropical Tethys ceased to exist when the Mediterranean basin lost contact with the nascent Indian Ocean about 16-18 mya (Vermeij 2012), but its biota continued to be tropical and highly diverse, roughly comparable to that to be found today in the tropical Indo-Pacific.



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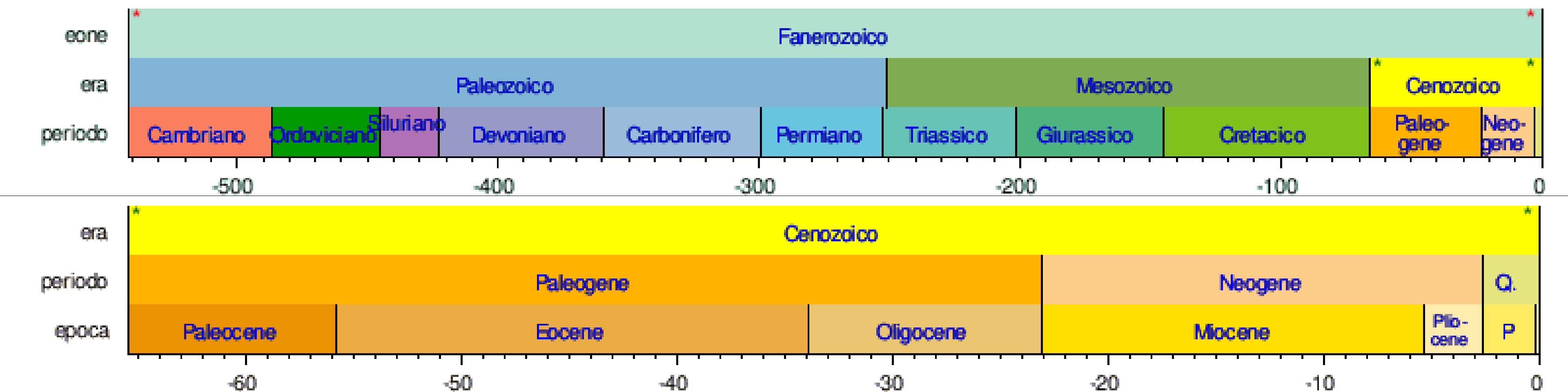
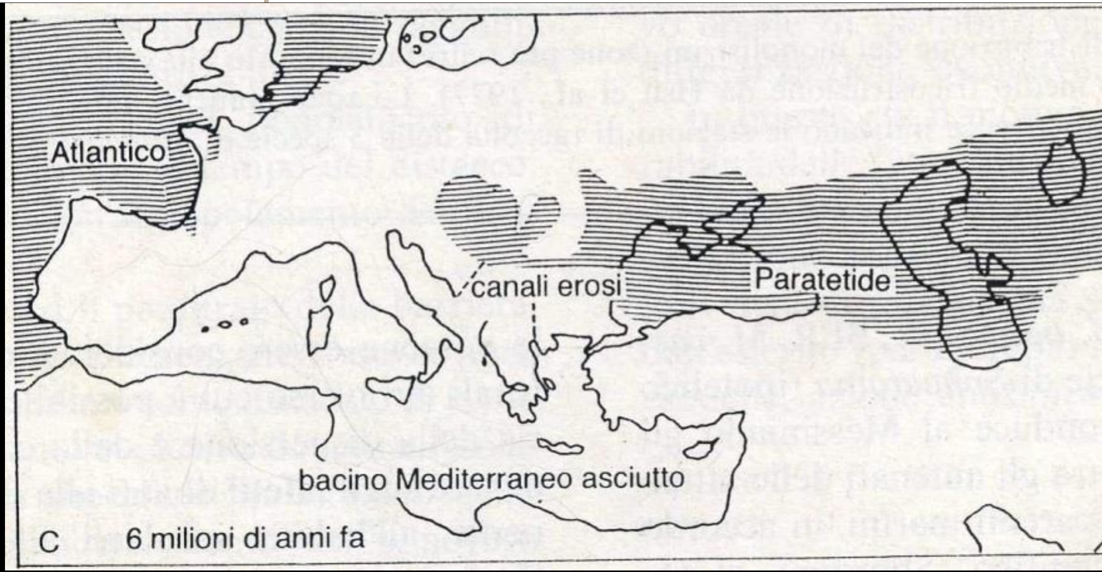


Scala dei tempi geologici

In the last phase of the Miocene, during the Messinian (about 6 mya), the connection with the Atlantic also closed, and the Mediterranean become an isolated sea. The progressive desiccation of this basin due to its negative water balance during the so-called “Messinian Salinity Crisis” (MSC) caused a mass extinction of the tropical Tethyan biota.



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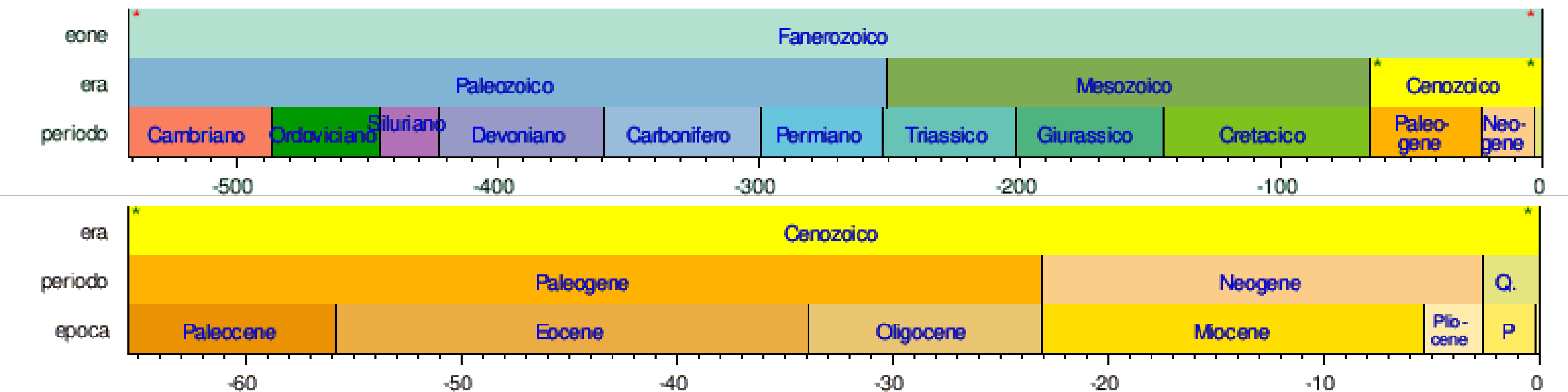

Scala dei tempi geologici

At the very end of the Miocene (5.5-5.3 mya), the Strait of Gibraltar re-opened and the Mediterranean was repopulated by species of Atlantic Origin, that were prevalently of (sub)tropical affinity (Bianchi 2007).

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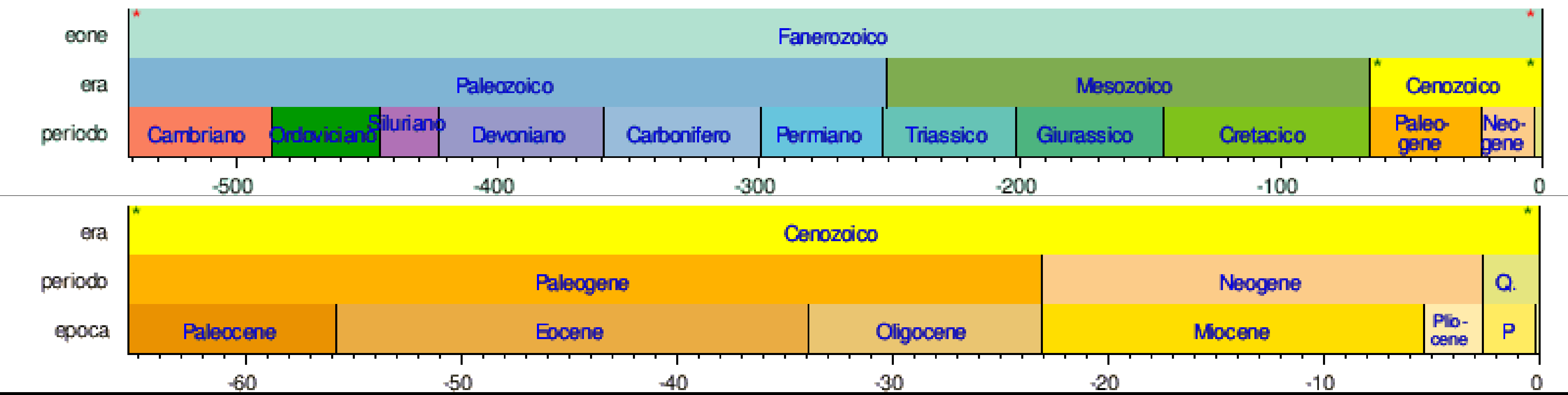
Changing Mediterranean Marine Biodiversity



Scala dei tempi geologici

The phases of the Pliocene were warm, especially during the so-called Pliocene Climate Optimum (between 3.6 and 2.6 mya), with a temperature 5 °C warmer than today and high sea levels of +20 to +35 m (Por 2009). Therefore, the Mediterranean biota preserved its tropical character.

At the beginning of the Pleistocene (the Gelasian) the glacial cycles started, with a sudden cooling about 2.6 mya (the Artic Glaciation) causing the end of the tropical biota of the Mediterranean, because most of Early Pliocene marine species became extinct, and the Mediterranean was invaded by cold water species from the northeastern Atlantic.

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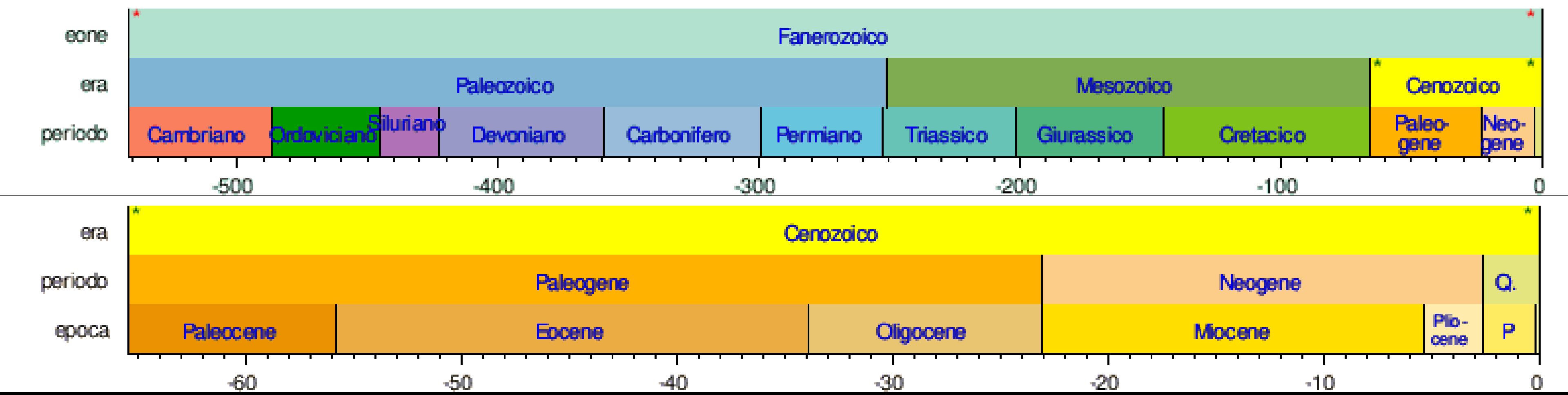
Changing Mediterranean Marine Biodiversity



Scala dei tempi geologici

In the Pleistocene, during the last interglacial, between 125,000 and 110,000 ya, with global temperatures 2–3 °C higher than today, the West African tropical fauna succeeded to reach the Levant.

After this warm period, and especially during the Last Glacial Maximum (20,000 ya; Pleistocene), the Mediterranean was invaded by cold-adapted North Atlantic species.

In recent decades, the ongoing global increase in temperature is noticeable all over the Mediterranean.

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Recent Mediterranean Biodiversity

According to a recent review of Mediterranean biodiversity (Coll et al. 2010), the number of macroscopic living species at present inventoried in this sea can be estimated at about 13.200 species (nearly 11,600 metazoans and 1,600 macrophytes).

This is a very high figure, if we consider that the Mediterranean only represents less than 0.8 % of the overall world ocean area, while the number of species that inhabit it represents about 5 % of total known recent marine species.

The present-day extraordinarily rich biota of the Mediterranean Sea is due to the outcome of the dramatic geological events (Miocene, Pliocene, and Pleistocene events), which subjected the biota to high evolutionary pressures and may have been the cause of frequent phenomena of extinction and speciation.

On the other hand, the complex topography of its coastline, with a number of islands and archipelagos of different sizes and fairly isolated sub-basins subject to a great variety of climatic and hydrological conditions, also promotes a high species diversity.

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Recent Mediterranean Biodiversity

Lejeusne et al. (2010) defined the Mediterranean as a factory designed to produce endemics; in fact, about a quarter of Mediterranean marine species are endemic. These endemics live together with species deriving from several waves of colonization of either temperate or tropical organisms.

Although the Mediterranean Sea is recognized as one of the most diverse regions on Earth, its depths are quite species-poor. Less than 10 % of Mediterranean animal species are present below a depth of 1,000 m, and less than 3 % below 2,000 m (Boudouresque 2004).

The Mediterranean deep waters are homothermic at about 13 °C and this limits the establishment of truly abyssal groups, which are typically adapted to colder waters (Emig and Geistdoerfer 2004).

The low diversity of the Mediterranean deep fauna may also be due to the Gibraltar sill (less than 350 m depth) acting as a physical barrier to the colonization from the richer Atlantic deep fauna (Bouchet and Taviani 1992).

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Recent Mediterranean Biodiversity

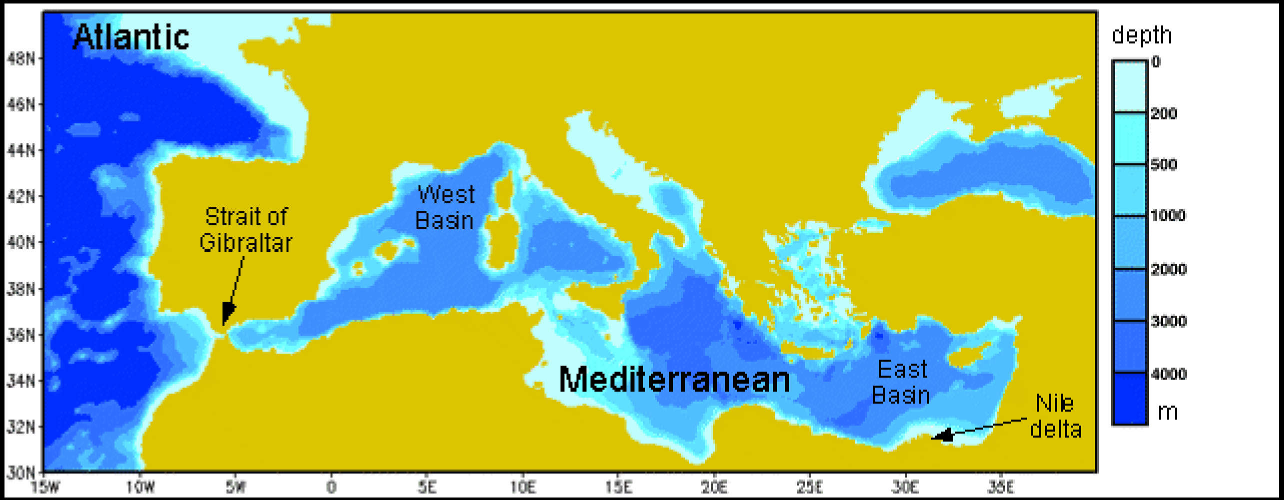

Image from: University of Wyoming 1998: The Strait of Gibraltar, and global climate. http://www-das.uwyo.edu/~geerts/cwx/notes/chap11/mow.html. Accessed 12/10/2017

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Recent Mediterranean Biodiversity

<u>Most of the present-day Mediterranean species are of Atlantic origin that entered after the MSC (Messinian Salinity Crisis)</u>, and therefore the Mediterranean biota presents a strong similarity to that of the northeastern Atlantic (European and African coasts).

Recently, the man-made contact through the <u>Suez Canal</u>, opened in 1869, started to <u>give access to hundreds of Indo-Pacific species</u> to the Mediterranean.

An increasing settlement by <u>tropical Atlantic newcomers</u> occurs entering the Mediterranean through the <u>strait of Gibraltar</u>.

According to Por (2009), the congruence of these two events, <u>the warming of the sea and the influx of the Indo-Pacific and tropical WestAfrican biota</u>, led to the present <u>re-establishment of the Tethyan tropical biota in the Mediterranean</u>.

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Recent Mediterranean Biodiversity

The main characteristics of the present-day Mediterranean Sea and its biota can be summarized as follow:

- Quasi-enclosed sea;
- Warm, salty, nutrient-poor water;
- Irradiance about 20 % greater than the mean irradiance incident at similar latitudes in the Atlantic Ocean;
- Seasonal thermocline from May–June to September–October;
- Homogeneous deep-water layers from 250–300 m to maximum depths that do not get colder than 12–13 ºC;
- Late winter phytoplankton boom;
- High diversity of habitats;
- High species richness and low abundance;
- High number of rare species;
- Mainly species of Atlantic origin with less abundant populations and generally smaller individual sizes;
- High rate of endemism (more than one-quarter of the species);

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Recent Mediterranean Biodiversity

The main characteristics of the present-day Mediterranean Sea and its biota can be summarized as follow:

- Shallow-water rocky bottoms dominated by frondose algae, mainly fucales of the genus *Cystoseira*;

Phaeophyta, Fucales, Cystoseiraceae

- Lush meadows of the seagrass *Posidonia oceanica*, which cover large areas between 0 and 40 m depth and are a key ecosystem;

Liliopsida, Najadales, Posidoniaceae

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Recent Mediterranean Biodiversity

The main characteristics of the present-day Mediterranean Sea and its biota can be summarized as follow:

- Proliferation of long-lived organisms within scyaphilous benthic communities;



Anthozoa, Alcyonacea, Plexauridae

- Low primary production, low fish production, and poor development of higher levels of the food chain (low pressures from top predators).

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Recent Mediterranean Biodiversity

In short:

- the Mediterranean is an oligotrophic sea (rich in oxygen and poor in nutrients);
- nutrient concentration decreases along both the west–east and the north–south directions, resulting in variations in the structure of the pelagic food web;
- species richness decreases from west to east;
- the Siculo-Tunisian sill (400 m deep) separates two distinct basins, the western and eastern basins, and has been traditionally considered as a geographical and hydrological barrier.

STS: Siculo-Tunisian sill

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Loss of Mediterranean Marine Biodiversity in Recent Times

Present day biodiversity is undergoing rapid alteration under the combined pressure of both global change and human impact.

There is a growing evidence that human activities are directly or indirectly resulting in the extensive loss of biodiversity and in an impoverishment of the Mediterranean marine biota.

Several species of elasmobranch are virtually disappeared (functionally extinct) from areas of the Mediterranean (Ferretti et al. 2008).


Carcharhiniformes, Sphyrnidae, *Sphyrna* spp


Carcharhiniformes, Carcharhinidae, *Prionace glauca*


Lamniformes, Lamnidae, *Isurus oxyrinchus*


Lamniformes, Lamnidae, *Lamna nasus*


Lamniformes, Alopiidae, *Alopias vulpinus*

Long-term population trends of large predatory sharks in the northwestern Mediterranean Sea, from early 19th and mid 20th century to early 21st century: sharks declined between 96 and 99.99% relative to their former abundance (Ferretti et al. 2008).

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Loss of Mediterranean Marine Biodiversity in Recent Times

Nine of fourteen species (64%) of canopy-forming algae (*Cystoseira* and *Sargassum*) that were originally reported in the Albères Coast (France, NW Mediterranean) at the end of the XIXth century are now disappeared (Thibaut et al. 2005).

Phaeophyceae, Fucales, Cystoseiraceae, *Cystoseria*

Phaeophyceae, Fucales, Sargassaceae , *Sargassum*

Loss of species are only the last steps of biodiversity decrease (Sala and Knowlton 2006), but functional (or ecological) extinction occurs long before species completely disappear. Population declines precede functional extinction, that occurs when a species is so rare that it no longer fulfil its natural eco-system function and, hence, becomes ecologically irrelevant.

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Natural Changes (Cyclical or Episodic)

Nature is subject to continuous natural changes, which not always happen gradually over the long-term. Some of them are cyclical or respond to episodic disturbances.

Fluctuations or pulses in populations and ecosystems are part of the natural dynamics of ecological systems. Many species show episodic recruitment pulses. After long periods of steady growth, the populations may experience mass mortality events. These high mortality events can lead to episodes of high recruitment that result in the recovery of populations and ultimately regulate their dynamics and structure (Navarro et al. 2011). Cyclical or episodic mortality events may serve to renew populations.

Outbreaks of common sea urchins can completely remove erect algae and other organisms, producing barren grounds.

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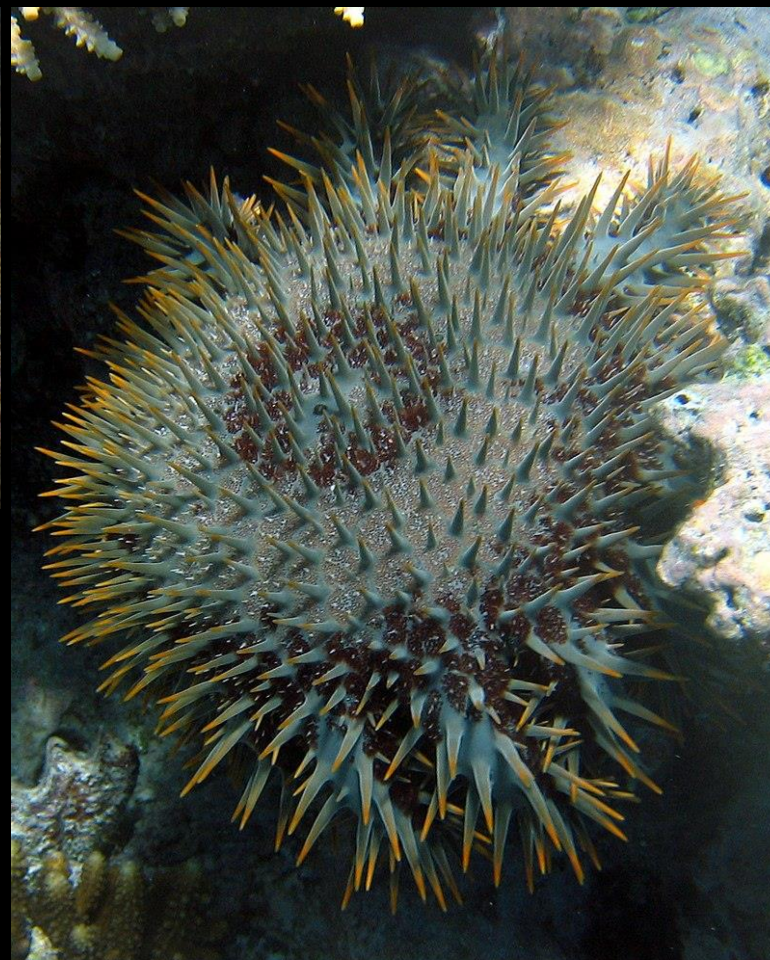

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Natural Changes (Cyclical or Episodic)

Natural episodic disturbances, such as extreme storms, diseases or herbivore outbreaks, are well known and there are numerous examples in the literature.

Recurrent diseases have been noted in species of some groups, such as bivalves (*Spondylus gaederopus* and some arcids), sea urchins (*Paracentrotus lividus, Arbacia lixula, Sphaerechinus granularis*), or large corneous demosponges (Cerrano and Bavestrello 2009).

Spondylus gaederopus; Bivalvia, Ostreoida, Spondylidae

Arcids; Bivalvia, Arcoida, Arcidae

Paracentrotus lividus; Echinoidea, Echinoida , Echinidae

Arbacia lixula; Echinoidea, Arbacioida, Arbaciidae

Sphaerechinus granularis; Echinoidea, Temnopleuroida, Toxopneustidae

Large corneous demosponges; Demospongiae, Dictyoceratida

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Natural Changes (Cyclical or Episodic)

<u>Severe storm events</u> cause massive mortalities of benthic organisms by direct wave action, or as a consequence of sediment and boulder displacement (García Rubiés et al. 2009).

26 September 2006

8 November 2011

7 November 2014

<u>To sum up, when analyzing the changes it should be taken into account that some of the observed changes could be just natural episodic or cyclical changes.</u>